REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
May 2005

3. REPORT TYPE AND DATES COVERED
Quarterly, 12/1/04-2/28/05

4. TITLE AND SUBTITLE
Quarterly Progress Report—Homopolar Motors Contract N00014-05-1-0123
Period of Performance: December 1, 2004-February 28, 2005

5. FUNDING NUMBERS
Contract # N00014-05-1-0123

6. AUTHOR(S)
I. R. McNab

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Advanced Technology
The University of Texas at Austin
3925 W. Braker Lane, Suite 400
Austin, TX 78759-5316

8. PERFORMING ORGANIZATION REPORT NUMBER
IAT.R 0410

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research Regional Office San Diego
Ballston Centre Tower One, 800 North Quincy Street
San Diego, CA 92121-3019, Fax (585) 677-6480

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views, opinions, and/or findings contained in this report are those of the author(s) and should not be considered as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*
This quarterly report provides a summary of support provided by the Institute for Advanced Technology (IAT) at The University of Texas at Austin (UT) to the Office of Naval Research (ONR) on the development of high-power superconducting homopolar motors for ship propulsion. One of the major issues facing the development of such machines for ship propulsion is the lifetime of the brushes used to transfer power from the homopolar motor rotor to the stator. Significant loss and wear polarity differences have been observed during the testing of such brushes, and ONR is developing a fundamental science program to address these issues. During this quarter, representatives from the IAT assisted ONR with the evaluation of proposals from a wide range of organizations that suggested approaches to identify and resolve the scientific reasons for the polarity differences.

14. SUBJECT TERMS
homopolar motor, rotor, stator, brush, brushless, rotary band contacts

15. NUMBER OF PAGES
7

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev.2-89)
Prescribed by ANSI Std. 239-18 298-102

Quarterly Progress Report

Period of Performance:

December 1, 2004–February 28, 2005

Prepared by:

Dr. Ian McNab
Principal Investigator

Institute for Advanced Technology
The University of Texas at Austin
3925 W. Braker Ln., Suite 400
Austin, TX 78759

Grant #: N00014-05-1-0123

Distribution: Electronic and US Mail
Recipients: S. C. Schreppler, ONR 334
K. Seward, ONR N66018
DTIC
NRL Code 5227

IAT.R 0410

QUARTERLY PROGRESS SUMMARY REPORT

Period reported: December 1, 2004 through February 28, 2005

1. Contract Summary

- Grant number: N00014-05-1-0123
- Period of performance: December 1, 2004 to October 31, 2005
- Total value of awarded Grant: $75,000.00
- Option No. 1: $75,000.00 for period November 1, 2005 to October 31, 2006
- Option No. 2: $75,000.00 for period November 1, 2006 to October 31, 2007

2. Contract Personnel

The Key Personnel involved in this effort are Dr. Ian R. McNab, Principal Investigator, and Dr. Chadee Persad. Dr. McNab is a Senior Research Scientist at The University of Texas at Austin and Director of the Electromagnetic Systems Division (ESD) at the Institute for Advanced Technology (IAT). He has had extensive prior experience and involvement in superconducting homopolar generators and motors and in the development of fiber and other brushes for these and similar machines. Dr. Persad is also a Senior Research Scientist at UT and is the Team Leader on High-Performance Materials at the IAT. From time to time, other technical experts working at the IAT who have relevant technical expertise may be consulted for comments and advice relating to this effort. The chief experts are: Dr. John A. Mallick and Dr. Kuo-Ta Hsieh. Dr. Mallick is a Research Scientist at UT and an expert in electrical machines. He is the Team Leader for Pulsed Power at the IAT. He has had extensive involvement in superconducting machines during his career at General Electric. Dr. Hsieh is a Research Scientist at UT and is co-Team leader for the Analysis and Code Development Section of the ESD. He is an expert on the development of high-capability codes and advanced computing.

3. Technical Report

3.1. Background

The support being provided by the IAT experts for ONR on this program is focused on the issues relating to the brushes being used and developed to transfer the load current to the superconducting homopolar motors being developed by General Atomics (GA) for ship propulsion. In common with earlier experience in the brush field, significant polarity differences have been observed during brush system tests at GA, the prime contractor for ONR on this program. The fundamental reasons for these polarity differences are not well understood, despite there having been many attempts to explain the effects. Generally it is found that the brush having a positive polarity operates with significantly higher voltage drop and wear rate than the brush having a negative polarity. From the GA data, it seems that the negative brushes will have a lifetime that is acceptable for fleet operation, but the wear rate of the positive brushes is questionable and may demand more frequent replacement than can be tolerated.

3.2. Integrated Project Team

Under the auspices of this grant, the IAT has been invited to participate in meetings of the integrated product team (IPT) set up by the Office of Naval Research (ONR) with GA. These meetings are generally scheduled on a monthly basis. During this quarterly period, Dr. Persad attended meetings at Anteon (Ballston, VA) on November 30, 2004 and at the Naval Surface Warfare Center (NSWC) (Philadelphia, PA) on January 19, 2005. At the first of these meetings, Dr. Persad provided a talk on the performance of contact materials and participated in a discussion on brushes. At the second meeting, Dr. Persad was involved in a review of White Paper proposals to ONR on brush research and subsequently submitted written recommendations to the ONR Program Manager. Conflicts with other scheduled meetings for IAT Army and Navy program sponsors unfortunately prevented Dr. McNab being present at these meetings. Drs. McNab, Persad and Hsieh are scheduled to attend the meetings at GA on May 3–5, 2005.

3.3. White Paper and Proposal Review

During January, Dr. McNab assisted in the review of the White Papers that were submitted to ONR following the Briefing to Industry meeting held at GA on December 16–17, 2004. Dr. McNab's inputs on the White Papers were provided to Anteon personnel (for ONR), and this led to a number of prospective research and development organizations being asked to provide full proposals. Dr McNab reviewed these proposals and provided an evaluation to Anteon personnel at the end of February. Based on all inputs received by the reviewers, ONR determined that several awards should be made. The areas of interest and proposals received fell into the three categories first suggested by Dr. McNab that are shown in Table I.

Table I. Proposals Evaluated

AUTHOR	INSTITUTE	TITLE
MACROSCOPIC BRUSH AND BRUSH HOLDER ISSUES		
Lewis	Moog Components Group	Improve Fiber Brush Design for HPM Applications
Bauer	IAP Research, Inc	Leaf Brush Proposal
Sondergaard	NSWCCD, Phila	Experimental Support of Homopolar Brush Program
Pourrahimi	SSI	Development and Application of Engineered Materials for Improved Performance of Metal Electrical Contact Brushes
Sondergaard, Lynch	NSWCCD, Phila	Modeling Metal Brushes in Support of Homopolar Brush Program
Moon	Cornell Univ.	Dynamics and Mechanics Issues in Homopolar Motor Brush Wear
Superczynski	Chesapeake Cryogenics	Gold Plated Silver Fiber Brushes for Homopolar Motors
Blake, et al	NSWCCD (Carderock/Phila)	Measurement of Thermal and Magnetic Fields In Brushes and Homopolar Motors

AUTHOR	INSTITUTE	TITLE
MICROSCOPIC PHENOMENA AND CONDUCTION ISSUES		
Blanchet	RPI	HPM Brush Wear: Effects of Duty Cycle and Surface Films
Salmeron, Tysoe	Lawrence Berkely Nat Lab / Univ. of Wisconsin	Study of the Surface Chemistry and Tribology of Cu Surfaces with CO_2 and Water Vapor
Sawyer Ziegert	Univ. of Florida	In-situ Lubrication of Sliding Electrical Contacts
Talke	Univ. CA San Diego	Brush Wear of Homopolar Motor
Lynch	NSWCCD, Phila	Characterization of Electron Acceptor and Electron Donor Based Electrolyte Additives for Metal Fiber Brush Current Collector Applications
MODELING OF BRUSH ENVIRONMENT AND MACHINE CONDITIONS		
Hsieh	IAT/Univ of Texas	Modeling & Simulation of the Homopolar Motor Test Apparatus to Determine the Influence of Electromagnetic and Structural Loads on the Performance of Brush Contacts
Sheppard Salon	Rensselaer Polytechnic Institute	Electromagnetic Analysis of the Superconducting Homopolar Motor
Mimnaugh (POC)	NSWCCD (Phila)	Homopolar Motor Field Modeling and Analysis
Mohammed	Florida International Univ.	Multi Physics Simulations of Superconducting Homopolar Motors
Warwick	Anteon Corp.	Analysis of brush Physics for a Homopolar Motor

3.4. GA data

Drs. McNab and Persad are continuing to review the weekly data reports provided by GA in preparation for the upcoming meetings scheduled at GA on May 3–5, 2005.

3.5. Possible Alternate Concept

One possible alternative that has been discovered by Dr. Persad, and that could be considered for use in low-speed homopolar motor applications, is discussed below. It has yet to be shown whether this will exhibit polarity differences of the type seen with fiber and other brushes. One important question to be answered is its current transfer capability per unit volume, which is an important issue for the design of superconducting machines. Related important parameters are, of course, the total (electrical plus frictional) losses, and the brush wear rate.

Rotary band contacts (RBCs) were identified and investigated as a potential solution to the brush wear problem in the superconducting homopolar motor. The RBC is a current transfer device that is a substitute for the metal fiber brush. The system is shown in Figure 1. It is described as a

"conductive wheel" by the industry developer.[1] This "conductive wheel" system carries power across components that rotate in relation to one another. This new design eliminates the slip ring/brush current transfer system. It consists of spoked wheels that roll within races integrated into or attached to the rotating components—the inner race on one component, the outer race on the other. A preload compresses the wheels into a mild ellipse, ensuring contact with the races so that power can pass between them continuously. Several wheels are needed to provide enough surface area for a high-power connection. For this type of duty, linkages attached to a hub in the center of the wheels create a "pinned necklace" planetary gear arrangement. The early design used wheels without any spokes, which limited the degree to which they could be deformed within the races without collapsing. The latest wheels feature an important design refinement that promises to further boost performance. Myrick came up with spiraled spokes that add stiffness and improve the electrical connection. They do so because they allow the wheels to be "squashed" more without collapsing, increasing the contact area with the races. And the spokes themselves provide an electrical pathway through the wheel. The spokes also allow the wheels to deform without shifting the center hub, which enables the linkages to function as well as helping the wheels adjust to any variations in the races. IAT has disclosed additional materials and design improvements that will better match this technology to the Navy SCHPM environment. These improvements will be described in a later report.

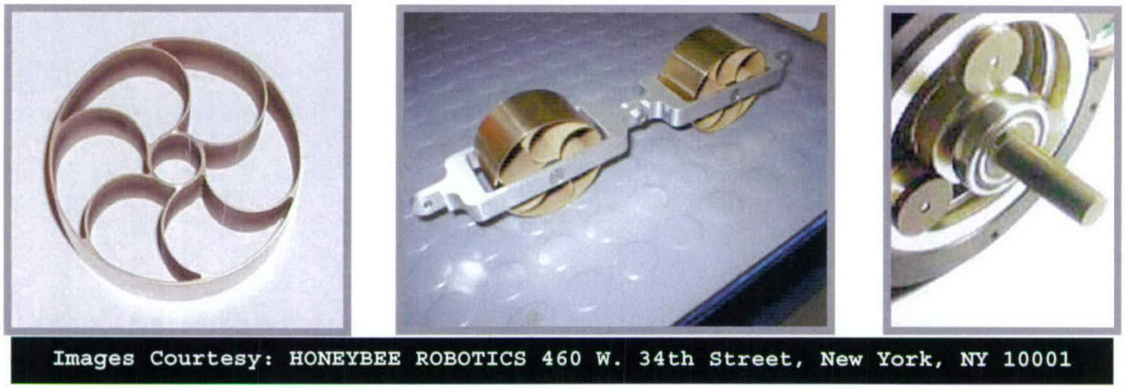

Figure 1. Rotary band contacts, one possible replacement for brushes in low-speed homopolar motor systems.

Abstracts of two recent US patents assigned to the Honeybee Corporation of New York are shown in Appendix A. It is noted that in the case of the more recent patent that "This invention was made with government support under Contract #NAS5-38071 awarded by NASA. The government has certain rights in the invention under 37 C.F.R. 401.14(E) (4)." The Missile Defense Agency has also listed this technology as one of its success stories in its SPRING 2005 issue, as shown in Appendix B.

4. Expenditures:
See financial attachment.

[1] Joseph Ogando, "A Shocking Metal," *Design News.* October 6, 2003.

APPENDIX A

United States Patent 5,501,604
Roopnarine et al.
March 26, 1996
Flexible band-gears for conducting power/signal across rotary joint

Abstract A flexible band-gear system has an ring gear assembly with bands in electrical contact with and a ring gear in mechanical engagement with corresponding bands and gears of planet gear assemblies which are in turn in electrical contact and geared engagement with a sun gear assembly mounted to a rotating shaft. Electrical power and/or an electrical signal can thus be conducted across a rotating joint which also transfers mechanical power. The flexible band-gear system can also be used in linear applications to transfer electrical power/signal via rolling contact with a linear band. The geared aspect of the system simplifies axial alignment and maintains the relative positions (within the ring annulus) of the planet gears. Electrical power and signal capacity can be varied with the number of planet gears in the system. Multiple channels are added using segmented contact bands and/or multiple contact band layers.

Inventors: Roopnarine; (New York, NY); Myrick; Thomas (New Providence, NJ); Kong; Kin Y. (Baldwin, NY)

Assignee: Honeybee Robotics, Inc. (New York, NY)

United States Patent 5,829,986
Kong
November 3, 1998
Single layer, multi-channel band-gear system for rotary joint

Abstract A multi-channel band-gear system for a rotary joint has a ring gear assembly with a conducting ring band in electrical contact with corresponding conducting bands of a set of intermediary planetary gears, which in turn are in electrical contact with a conducting sun band of a sun gear assembly. The ring band is formed with a plurality of conducting segments, which are electrically insulated from each other and positioned angularly in a circumferential direction of the ring gear, such that separate electrical power/signal channels are formed across the rotary joint. In a preferred embodiment having continuously connected channels, the ring band has four conducting segments at 90 degree intervals, the sun band has two conducting segments at 180 degree intervals, and three planetary bands are in rolling electrical contact at 120 degree intervals between the ring band segments and the sun band segments, forming two continuously connected channels in a single layer of the band-gear system. Multiple sets of ring gear, planetary gear, and sun gear assemblies may be used in a stacked configuration in a single axial layer to further increase the number of channels provided through the band-gear system.

Inventor: Kong; Kin Yuen (Baldwin, NY)

Assignee: Honeybee Robotics, Inc. (New York, NY)

Appendix B

CONDUCTIVE WHEELS OFFER CLEANER SOLUTION THAN RINGS OR BRUSHES

Anybody who has used slip rings and carbon brushes in rotating equipment is familiar with their wear, dust, and noise issues. When the parts wear down, they create dust. In operation, electrical and acoustical noise is significant.

Stoked for spokes. *Honeybee's conductive wheels can be compressed to increase surface contact area, which translates directly into high current-carrying capability.*

Addressing these debris issues, Honeybee Robotics, Ltd. (New York, NY), has developed new hardware that eliminates the need for slip rings or brushes yet efficiently transfers current into or out of rotating machines. The hardware ultimately will find new applications in mechanisms for boat radars, printing presses, and other industrial machinery.

Honeybee's technology relies on spoked, wheel-like rings made of beryllium copper (BeCu) spring material. The rings sit slightly compressed and sandwiched almost like ball bearings between two larger rings in the mechanism. (The assembly resembles a planetary-gear arrangement, in which smaller "planet" gears rotate around a central "sun" gear.) Electricity passes from the outer ring, through the BeCu wheels, and into the inner ring, delivering power to a rotating machine. As one ring turns inside the other, the BeCu wheels roll along between them and, due to the spring compression, are constantly in contact with both the inner and outer rings.

Honeybee engineers boast that their design is much cleaner and therefore more reliable than brushes and slip rings.

Honeybee engineers boast that their design is much cleaner and therefore more reliable than brushes and slip rings. "There's never particle generation. And the wear concerns aren't there either," said Tom Myrick, chief engineer of Honeybee. The lack of serious friction and wear also means that the rings involved in this mechanism should last longer than brushes and slip rings, he said. Moreover, the rolling motion of the wheels means devices using them would operate more quietly and also generate less electrical noise than brushes and slip rings.

The versatility of the spoked wheel and the planetary-gear-like arrangement of the wheels and rotating rings is key. Wires or rods could be used in the hubs of the spoked wheels to control their positions and keep them from straying when using many wheels or multiple layers of wheels and rotating rings, according to Myrick. Moreover, Honeybee can tune the dimensions and shapes of the spokes as well as the thickness of the wheel surface, effectively controlling the stiffness of the wheel as needed for the task at hand. "By adding spokes and leaving the wall thin, you increase its stiffness, but you don't add any extra stress to the system," Myrick said. The spokes also could act as a current-carrying path, theoretically cutting in half resistance in the wheels.

The design of the wheels also can provide a higher current-carrying capability than might be achieved with brushes and slip rings. The wheels can be compressed to increase surface contact area between them and the rings. The increased contact area of the surfaces translates directly into high current-carrying capability, Myrick said.

Know-how for Honeybee's technology has come from work on an MDA-funded project. The agency originally funded the company with a Phase II SBIR award to develop a lightning protection system for the revolving nose turret for the Airborne Laser (ABL) program. The ABL project will put a movable high-power laser on the nose of an airplane, allowing the plane to strike at missiles from the air. Honeybee envisions its wheels embedded in the turret, allowing the ABL to channel a sudden electrical surge and avoid damage to equipment in the nose.

On the commercial front, Honeybee wants to get its technology in front of manufacturers of mechanisms that involve rotary motion and require electricity. Such mechanisms could include boat radars, industrial power washers, and printing presses, as well as other industrial machinery. The company seeks help discovering new applications for the technology. It has patents on a related technology and has a patent pending on its current MDA-funded design.

—*S. Tillett*

CONTACT INFORMATION:

Tom Myrick
Honeybee Robotics, Ltd.
460 W. 34th Street
New York, NY 10001
Tel: (646) 459-7806
Fax: (646) 459-7898
E-mail: myrick@honeybeerobotics.com
Web: www.honeybeerobotics.com